809C
UNIVERSAL PROBE CARRIAGE

OPERATING AND SERVICE MANUAL

HEWLETT hp PACKARD

HP 809C

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OPERATING AND SERVICE MANUAL

MODEL 809C
UNIVERSAL PROBE CARRIAGE

SERIAL 1 AND ABOVE

with

Model 816A Coaxial Slotted Line
Model 810B Waveguide Slotted Section
Model 447B Untuned Probe
Model 444A Untuned Probe
Model 442B Broadband Probe
Model 440A Detector Mount

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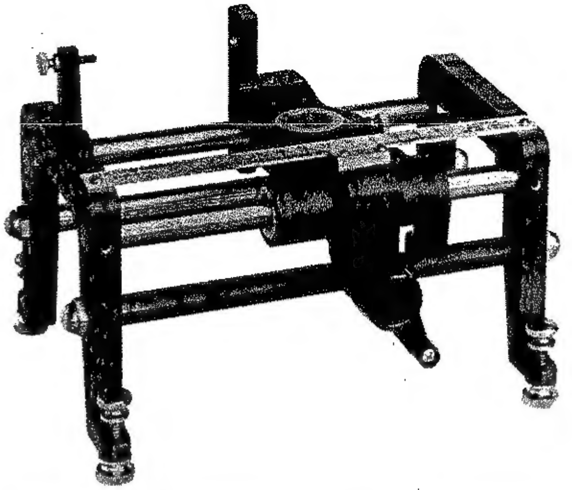
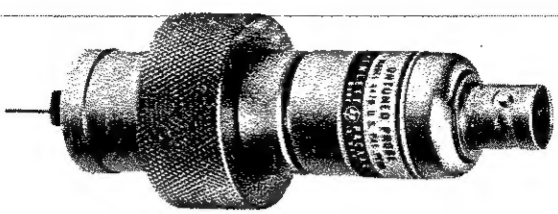


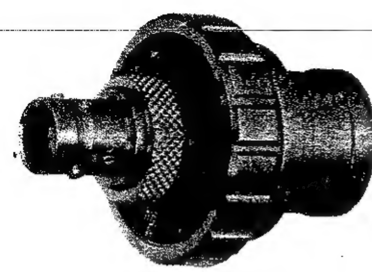
MODEL 809C UNIVERSAL PROBE CARRIAGE

MODEL 810B WAVEGUIDE SLOTTED SECTION

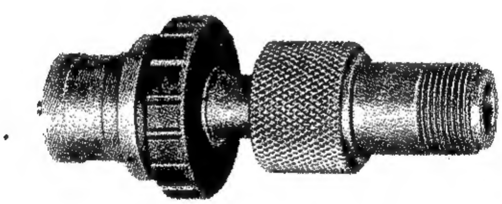
MODEL 816A COAXIAL SLOTTED LINE



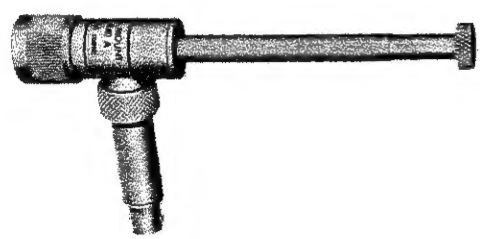
MODEL 447B UNTUNED PROBE



MODEL 444A UNTUNED PROBE



MODEL 442B BROADBAND PROBE



MODEL 440A DETECTOR MOUNT

Figure 1-1. Model 809C Universal Probe Carriage and Accessories

SECTION I
GENERAL INFORMATION

1-1. GENERAL.

1-2. The HP Model 809C Universal Probe Carriage is a precision-built mechanical assembly designed to operate with a number of interchangeable slotted lines. These include HP 810 Series Waveguide Slotted Sections covering frequency ranges from 3.95 GHz to 18.0 GHz, and the HP Model 816A Coaxial Slotted Line 1.8 GHz to 18.0 GHz. This carriage may also be used with the older Model 806B in the 3.0 to 12.0 GHz region.

1-3. The Model 809C greatly simplifies waveguide measurements over a number of frequency bands as it eliminates the need for a probe carriage for each waveguide band and waveguide sections can be interchanged in 30 seconds or less. It can be used with HP Model 444A Untuned Probe, HP Model 440A Detector and MHz Model 442B Broadband Probe in combination, and the Model 447B Untuned Probe. The unit has a centimeter scale with a vernier reading to 0.1 millimeter. Provision is also made for mounting a dial gauge when more accurate readings are required. The probe carriage moves on two ground stainless steel rods and a conventional ball bearing forms the third point of suspension.

1-4. MECHANICAL INSPECTION.

1-5. Unpack the instrument upon receipt and inspect it for signs of physical damage. If there is any apparent damage, file a claim with the carrier and refer to the warranty page in this manual. See Paragraph 4-5 for performance check procedures.

1-6. ACCESSORIES AVAILABLE.

1-7. MODEL 810B WAVEGUIDE SLOTTED SECTIONS. Waveguide slotted sections for use with the Model 809C Universal Probe Carriage are listed in Table 1-2.

Table 1-1. Specifications

MODEL 809C UNIVERSAL PROBE CARRIAGE Carriage: Mounts all HP 810B Waveguide Slotted Sections and HP 816A Coaxial Slotted Sections. Probe Required: HP 447B Untuned Probe, HP 444A Untuned Probe, or HP 442B Broadband Probe.	Connectors: One APC-7, one Type N female. Type N connector is stainless steel and mates compatibly with Type N connectors whose dimensions conform to MIL-C-39012 or MIL-C-71. Either end can be connected to the load; shorting connectors furnished for load phase-angle determination.
Probe Travel: 10 cm. Calibration: Metric. Vernier permits readings to 0.1 mm. Provision for dial gauge installation. Leveling Screws: Knurled thumb screws provided on all four carriage legs. Accuracy: When used with waveguide sections, standing wave ratios to 1.02 can be read easily. Slope error of slotted sections can be eliminated by adjustment. Dimensions (maximum envelope): 8 7/8 in. long, 6 13/16 in. wide, 5 13/16 in. high (226 x 174 x 148 mm). Weight: Net, 4 lb (1,8 kg). Shipping, 4 lb (2,3 kg). **MODEL 816A COAXIAL SLOTTED LINE** Frequency Range: 1.8 to 18 GHz with HP 447B Probe. Impedance: 50Ω ± 0.2 Ω. Carriage: Fits HP 809C Universal Probe Carriage.	Residual SWR and (Reflection Coefficient) *APC-7 Connector: 1.8 to 8 GHz: $\leq$ 1.02 (0.01). 8 to 12.4 GHz: $\leq$ 1.03 (0.015). 12.4 to 18 GHz: $\leq$ 1.04 (0.02). Type N connector: 1.8 to 8 GHz: $\leq$ 1.04 (0.02). 8 to 12.4 GHz: $\leq$ 1.05 (0.024) 12.4 to 18 GHz: $\leq$ 1.06 (0.029). Slope and Irregularities: 0.1 dB per half wavelength, 0.2 dB maximum cumulative. Length: 9 3/4 in. (248 mm). Weight: Net, 1 1/4 lb (0.6 kg). Shipping, 3 lb (1,4 kg). Accessories Furnished: 11512A Short, Type N male; 11565A Short, APC-7. Option 11: Both connectors APC-7 (11565A, APC-7 short, supplied). Option 22: Both connectors Type N, one male, one female (11512A and 11511A Type N female short supplied).

Table 1-1. Specifications (Cont'd)

MODEL 810B WAVEGUIDE SLOTTED SECTION

Model	G810B	J810B	H810B	X810B	P810B
Frequency Range (GHz)	3.95-5.85	5.30-8.20	7.05-10.00	8.20-12.40	12.40-18.00
Waveguide I.D. (in.)	1.872 ± 0.004 x 0.872 ± 0.002	1.372 ± 0.002 x 0.622 ± 0.001	1.122 ± 0.002 x 0.497 ± 0.001	0.900 ± 0.002 0.400 ±0.001	0.622 ± 0.001 x 0.311 ± 0.001
Fits Waveguide Size Nom. O.D. (in.) (EIA)	2 x 1 WR187	1 1/2 x 3/4 WR 137	1 1/4 x 5/8 WR112	1 x 1/2 WR90	0.702 x 0.391 WR62
Equiv. Flange	UG-407/U	UG-441/U	UG-138/U	UG-135/U	UG-149/U
Length (in.) (mm)	10 1/4 260	10 1/4 260	10 1/4 260	10 1/4 260	10 1/4 260
Net Weight (lb) (kg)	2 1/8 0,96	2 0,9	1 3/8 0,63	1 1/8 0,55	7/8 0,39
Shipping Weight (lb) (kg)	4 1,8	3 1,4	2 0,9	2 0,9	2 0,9

Slope and Iregularities: 1.01 SWR.
Discontinuity due to slot results in SWR of less than 1.01.

Carriage: Fits HP 809C Universal Probe Carriage.

* Amphenal, RF Connector Division of Amphenol Corp., Danbury, Conn. These connectors are 7mm, bi-sexual connectors, any two of which mate with each other.

MODEL 447B
UNTUNED PROBE

Frequency Range: 1.8 to 18 GHz. For use with HP 816A Coaxial Slotted Line.

Output Connector: BNC female.

Detector: Supplied.

Dimensions (maximum envelope): 3-1/2 in. long, 1-1/8 in. diameter (89 x 29 mm). Requires 3/4 in. (19, 1 mm) mounting hole.

Weight: Net, 6 oz (0,17 kg). Shipping, 1 lb (0,45 kg).

MODEL 444A
UNTUNED PROBE

Frequency Range: 2.6 to 18.0 GHz (4 to 18.0 GHz with HP 816A).

Output Connector: BNC female.

Detector: Supplied.

Accessory Furnished: 11506A Probe Tip Kit (8 Tips).

Dimensions (probe flush with housing): 1 1/4 x 2 1/16 in. (32 x 52 mm).

Weight: Net, 6 oz (0,17 kg). Shipping, 8 oz (0,23 kg).

Table 1-1. Specifications (Cont'd)

MODEL 442B
BROADBAND PROBE

Frequency Range: 2.6 to 18.0 GHz (4 to 18.0 GHz with HP 816A).

Dimensions (probe flush with housing): 1 1/4 x 3 1/8 in. (32 x 79 mm).

Weight: Net, 6 oz (0,17 kg). Shipping, 8 oz (0,23 kg).

MODEL 440A
DETECTOR MOUNT

Frequency Range: 2.4 to 12.4 GHz.

Detector (not supplied): 1N21 to 1N23 silicon crystals or Type 821 barratter.

Tuning: Single stub.

Connectors: Type N male (RF input); BNC female (detector output).

Dimensions: 1-3/16 x 2-13/16 x 4-1/2 in. (21 x 72 x 114 mm); stub adjustable to 6-13/16 in. (173mm).

Weight: Net, 5 oz (0,14 kg). Shipping, 1 lb (0, 45 kg).

Table 1-2. Model 810B Waveguide Slotted Sections

Model	Frequency Range GHz	Fits Waveguide size (in.)	Equivalent Flange
G810B	3.95 to 5.85	2 x 1	UG149A/U
C810B	4.90 to 7.05	1.718 x .923	
J810B	5.20 to 8.20	1-1/2 x 3/4	UG344/U
H810B	7.05 to 10.0	1-1/4 x 5/8	UG51/U
M810B	10.0 to 15.0	.850 x .475	
X810B	8.20 to 12.4	1 x 1/2	UG39/U
P810B	12.40 to 18.0	.702 x .391	UG419/U

SECTION II
OPERATING INSTRUCTIONS

2-1. ASSEMBLY.

2-2. MOUNTING A SLOTTED SECTION.

2-3. A slotted section is inserted in the carriage, slot-side-up, with the four mounting holes in the slotted section matching the four mounting holes in the carriage. The clearance between the end frame shoulders and the slotted section is about 0.0001 inch and the slotted section must be kept square as it mates with the shoulders.

CAUTION

Remove probe first to avoid damage. Do not force slotted section into the end frame.

2-4. The top side of the slotted section should meet the four carriage shoulders accurately. This can be checked by holding the slotted section in place before the screws are inserted and tipping it slightly. A slight clearance may exist under one shoulder, but should not exceed 0.002 inch.

2-5. Four socket-head cap screws (HP part no. 3030-0024), which are provided, fasten the slotted section to the carriage. These screws should be set snugly, with a 9/32" -across-the-flats Allen wrench, taking care that the slotted section does not bind in the carriage as the screws are set.

2-6. With the slotted section properly secured to the carriage, about 0.010 inch clearance will exist between the movable carriage and the top of the slotted section; with the unit assembled, the movable carriage should slide freely from one end to the other.

2-7. PROBE.

2-8. With the slotted section properly secured to the carriage, a suitable probe may be inserted in the hole centered on the movable carriage. Be sure that the tip of the probe is centered in the slot. This may be checked in waveguide by sighting down the inside of the slotted section and moving the adjustable carriage with the probe along the slot. It is not necessary for the probe to be absolutely centered, but the probe tip must not touch the slot edge.

2-9. The probe depth on slotted section detector mounts may be adjusted by unlocking the knurled head on the mount itself. Probe depth adjustment may be made by varying the depth of the detector element and relocking the knurled head. At some frequencies it will be found that probe depth has a marked effect on the tuning of the detector. If this condition is encountered, readjust the depth of the probe for satisfactory, but loose, coupling (minimum penetration).

2-10. CARRIAGE SCALE.

2-11. For waveguide sections, the scale and vernier on the front of the carriage are aligned to read the distance in centimeters from the right flange face of the slotted section to the probe. Since the position of the slotted section varies a small amount during assembly, the carriage scale should be adjusted after the slotted section has been assembled. Two machine screws mount the scale to the carriage and can be loosened to adjust the scale. The scale position may be checked electrically by placing a shorting plate on the output flange.

2-12. A fitting to the rear of the carriage is designed to accept a standard dial-type indicator for measurements that require precise positioning (for example, the measurement of null widths of high SWR's or measurement of SWR by the nodal-shift method). A stop on the rear rod may be adjusted to calibrate a dial indicator to a desired reference. A 25 millimeter dial indicator with dial graduations of 0.01 millimeter is recommended for this purpose. *

2-13. LEVELING.

2-14. Even though the carriage is sufficiently rigid to withstand normal working strains, it is desirable under all conditions of measurement to adjust the leveling screws on the feet of the carriage so that the frame is supported uniformly at all four corners. Particular care should be taken with this adjustment when waveguide sections are suspended by a slotted section mounted in the carriage, since any undue strain could cause distortion and error in measurements.

2-15. To adjust the leveling blocks in the mainframe, refer to paragraph 2-15c.

2-16. OPERATING CHECKS.

a. With slotted section properly assembled to the probe carriage, connect a signal generator of the desired frequency and a load to the slotted section. The load should have an SWR of 2:1 or better.

b. Connect a standing-wave indicator to the carriage probe and slide the carriage to observe the standing-wave pattern.

c. If the unit has been properly assembled, the amplitude of successive peaks of the standing-wave pattern should be within approximately one percent of each other. When precise measurement is demanded, the position of the slotted section may be adjusted slightly within the carriage as follows to equalize the

*Dial measurement gauges for use with the Model 809C are as follows: B.C. Ames Co., Waltham, Mass., Model 282M; L. S. Starrett Co., Athol, Mass., Model 665M.

standing-wave peaks. With a short connected, determine which end of the slotted section has the increasing voltage peaks (high end). Loosen slightly the two screws holding the high end of the slotted section and tighten the setscrew in the middle of the end frame with a 1/16" -across-the-flats Allen wrench. Recheck and repeat adjustment if necessary.

2-17. MECHANICAL DRIVE.

2-18. Although the Model 809C is designed particularly for manual applications, it is rigidly constructed and may be used in a motor drive application for production test or in cases where standing-wave patterns are presented on an oscilloscope. The positioning knob and pinion gear may be removed for such applications, permitting the carriage to run freely. The carriage may be connected to a motor drive unit that provides a reciprocating motion. The reciprocating motion should be limited to a few cycles per second.

2-19. For oscilloscope or X-Y recorder presentation, mount a contact on the back side of the movable carriage to wipe a fixed resistance card as the carriage moves. With a dc voltage supply connected to the resistance card, the contact receives voltages proportional to the linear displacement of the carriage. This voltage is applied to the horizontal sweep of an oscilloscope or X-Y recorder allowing the standing-wave pattern to be presented accurately both in amplitude and position.

2-20. CRITICAL MOUNTING DIMENSIONS.

2-21. Slotted sections may be made for use with the Model 809C to accomodate special waveguide sizes. Figure 2-1 shows the critical mounting dimensions required for the machining of any special slotted sections.

2-22. EQUIPMENT CONSIDERATIONS.

2-23. Excessive probe penetration is a major source of error in slotted line measurements when measuring standing-wave ratios of 10:1 or less. Probe penetration can be considered as an admittance shunting the line, the effect becoming greater as probe penetration is increased. As probe penetration is decreased, however, the amplitude of the signal drops; for a good reading, a signal level must be high enough to be above the combined noise of crystal and indicator. Thus, when measuring small standing-wave ratios, equipment used in the measurement system should have features that will contribute to obtaining a useful signal with probe penetration as slight as possible.

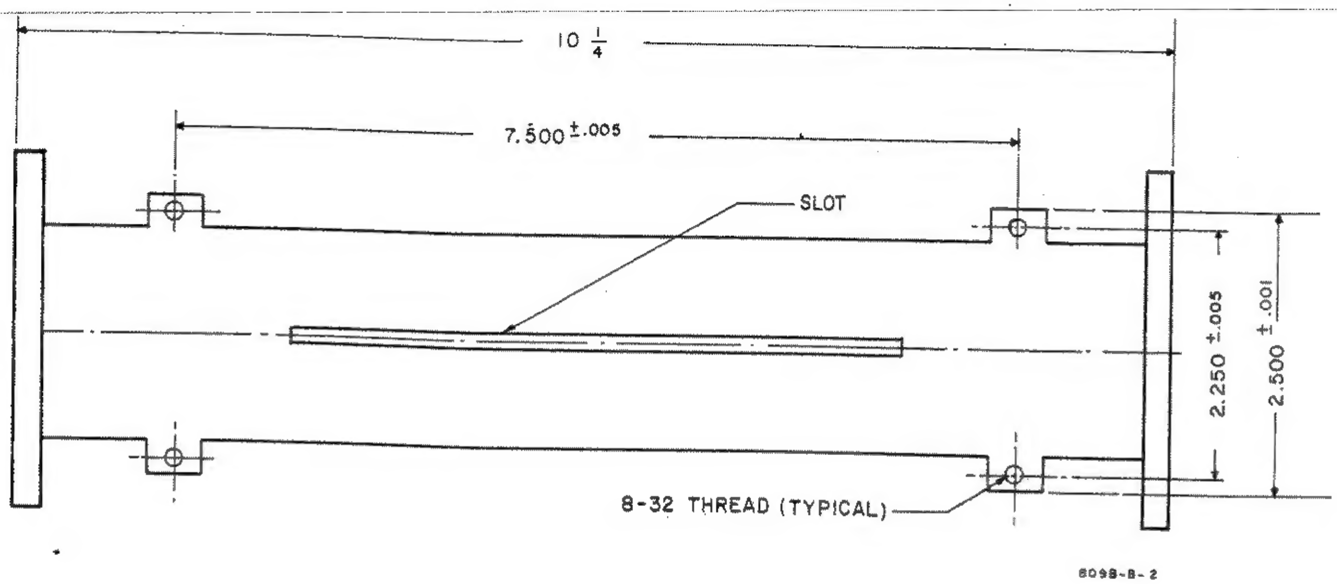


Figure 2-1. Critical Mounting Dimensions

Table 2-1. Recommended Signal Sources

Frequency Range (MHz)	Signal Source, HP Model Number	Source of Mod. Volts	Mod. Volts Source HP #
1,800 - 4,000	616A/B UHF Signal Generator	external	211A Square Wave Gen.
3,800 - 7,600	618B SHF Signal Generator	internal	
7,000 - 11,000	620A SHF Signal Generator	internal	
10,000 - 15,500	626A SHF Signal Generator	internal	
15,000 - 21,000	628A SHF Signal Generator	internal	
2,000 - 4,000	8692A/B w/8690A Sweep Oscillator	internal	
4,000 - 8,000	8693A/B w/8690A Sweep Oscillator	internal	
8,000 - 12,400	8694A/B w/8690A Sweep Oscillator	internal	
12,000 - 18,000	8695A w/8690A Sweep Oscillator	internal	

2-24. SIGNAL SOURCE.

2-25. The source used should be capable of delivering at least 1 milliwatt of power output and have an output low in harmonics and incidental FM. The RF output must be amplitude-modulated at the frequency to which the standing-wave indicator is tuned; generally, this is a 1 kHz square wave. The signal generator must have an internal source of 1 kHz modulating voltage or must have a modulating voltage input. Recommended signal sources are shown in Table 2-1.

2-26. LOW-PASS FILTER.

2-27. Connect filter at the signal source output to eliminate harmonics. The HP Model 362A series filters that have at least 40 dB attenuation in the stop band are suitable. Model 281B waveguide-to-coax adapters must be used with these waveguide filters, when working with coaxial slotted sections.

2-28. PAD.

2-29. There should be isolation between the signal source and the slotted section. The HP Model 375A series or the HP Model 382A series Variable Attenuators are recommended for waveguide; the HP Model 8491A or 8491B, 8492A Attenuators, and Model 354A Step Attenuator for coaxial applications.

2-30. INDICATOR.

2-31. A high-gain, tuned voltmeter should be used. Since the crystal should be operated in its square-law region, the indicator should have square-law calibration. The HP Model 415B/E Standing-Wave Indicator is suitable. The Model 415B input normally is tuned to 1 Hz, but plug-in filters tuned to frequencies of from 315 to 2020 hertz are available at nominal cost. Alternatively, a dc oscilloscope or X-Y recorder can be used as a dc indicator; modulation is not needed in this case.

2-32. BASIC MEASUREMENT TECHNIQUES.

2-33. Basically, the measurement of standing-wave ratio consists of setting the probe at a voltage maximum position and setting the gain of the Model 415B/E so that a scale of 1.0 is obtained. The carriage is then moved along the line for a voltage minimum, and the SWR is indicated directly on the scale of the Model 415B/E. This method, while straightforward and simple, can lead to serious errors under certain conditions. Section III of this manual discusses these errors and suggests techniques for minimizing their effects.

2-34. Generally, the impedance characteristic of the load is obtained by measuring the position of the minimum in a standing-wave pattern. A shift in position occurs when a known load replaces the load under test. For convenience, the reference point is usually the load connector on the slotted section and the known load is a short circuit or shorting plate.

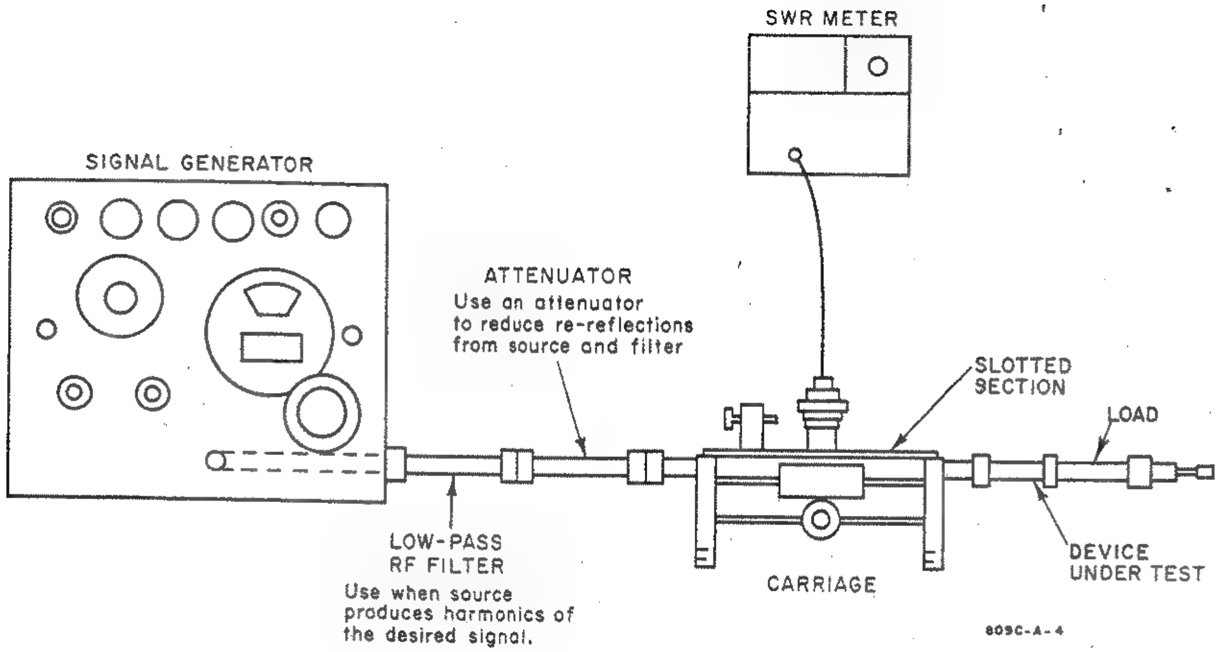


Figure 2-2. Typical Setup for Measuring SWR

2-35. FIXED FREQUENCY MEASUREMENTS.

2-36. MEASUREMENT OF STANDING-WAVE RATIO.

2-37. DIRECT READING VOLTMETER METHOD. A detector and direct reading indicator are used in the simplest method for measuring SWR. When loose probe coupling is maintained, this method is sufficiently accurate for the measurement of most standing-wave ratios up to 10:1.

2-38 FIXED LOAD METHOD. Connect equipment as shown in Figure 2-2 and proceed as follows:

a. Slide the carriage along the slotted section and locate a voltage maximum position. Tune probe detector circuit (if tuneable) for maximum voltage.

b. Adjust probe depth for the least coupling that will allow a reading on the Model 415B/E with the 415B/E RANGE switch set at 40 dB.

c. Adjust GAIN control on the Model 415B/E so that the meter indicates 1.0.

d. Slide the carriage along the slotted section to find a voltage minimum position. DO NOT retune probe or detector circuit.

e. Read SWR directly on the meter scale of the Model 415B/E in conjunction with the step attenuator (RANGE switch).

2-39. SLIDING LOAD METHOD. (for use with two-port devices). The previous method measures the total reflection (incident plus any residual in slotted section plus that of load). The reflection of the load can be eliminated by the use of a sliding load. The instrument setup is identical with the previous one except that the device under test is terminated in a sliding load.

2-40. Reflections from the load can be distinguished from those caused by a discontinuity in the transmission system. A discontinuity causes a fixed-phase reflection from the movable load can be made to occur in any phase by moving the load. In a typical SWR measurement, moving the load will cause the meter pointer of the SWR meter to vary as the phase of the reflection is varied.

2-41. To measure the SWR of the transmission system, the sliding load is connected in place of the usual load at the end of the system. Then, adjusting both the position of the probe carriage on the slotted section and the position of the sliding load, the highest obtainable SWR is sought and measured. This measurement requires some care, since the settings are interdependent. A second SWR measurement is made. To make this measurement, first return the probe to the position of the original maximum or peak. Adjust the sliding load to obtain a minimum reading on the SWR Meter (maximum needle deflection to left). The load should be adjusted while the probe carriage is still positioned at the point of the former maximum. Read SWR on SWR Meter. A second SWR smaller than the first is obtained. If the first SWR reading is SWR_1 and the second reading is SWR_2, the SWR of the transmission system is

$$SWR = \frac{SWR_1}{SWR_2}.$$

2-42. The above measurements are shown in Figure 2-3, which represents the voltage waves in the transmission system in vector form. Vector E_i, the incident wave, travels down the system and a partial reflection E_d occurs at the device under test. A second partial reflection E_L occurs at the sliding load.

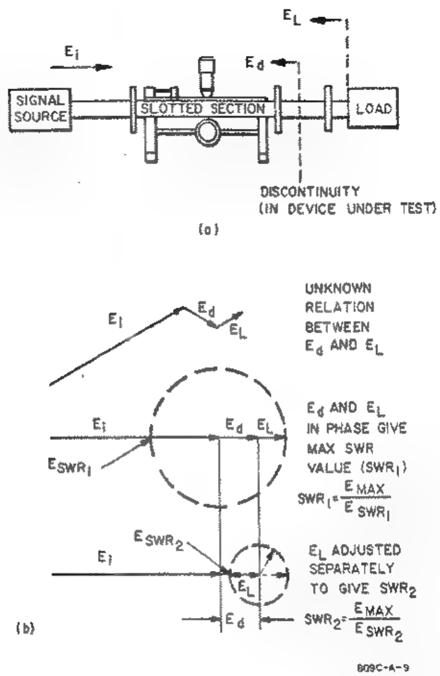


Figure 2-3. (a) Typical set-up using sliding load. (b) Relation of incident and reflected voltages when making measurements with a sliding load.

2-43. The phase of reflection E_d can, in effect, be adjusted by changing the position of the probe carriage on the slotted line. Similarly, the phase of the reflection E_L can be adjusted by positioning the sliding load. In the first SWR measurement, the phases of E_d and E_L are adjusted by positioning the probe carriage and load so that the two reflections reinforce each other. This arrangement gives the highest obtainable value of reflected voltage and thus the highest SWR. The SWR has the value

$$SWR = \frac{E_L + (E_d + E_L)}{E_L - (E_d + E_L)} .$$

2-44. In the second SWR measurement when the probe is returned to the position of the maximum, the phase of only E_L is adjusted. Under this condition, the reading has the value

$$SWR = \frac{(E_L + E_d) + E_L}{E_L + E_d - E_L} .$$

Since the reflected waves are small in magnitude, this second SWR reading is essentially the SWR of the sliding load. In case of question, the SWR can also be calculated from the more accurate expression

$$SWR = \frac{SWR_2 + 1}{SWR_2 - 1 + 2\,\frac{SWR_2}{SWR_1}} \cong \frac{SWR_1}{SWR_2} .$$

2-45. For small values of SWR_2, the above expression can be approximated by SWR_1 since the denominator is almost 1. In this case, the SWR can be measured by adjusting for maximum SWR, setting the SWR to 1.0, and then moving the carriage and the sliding load for a minimum. Repeat these adjustments as there may be some interaction. The reading on the SWR meter is now the SWR for small values of SWR.

2-46. DOUBLE MINIMUM METHOD. This method is employed when it is desired to measure a large SWR. It is based on the fact that the shape of an SWR pattern at minimum point will approximate a parabola when the magnitude of the SWR exceeds 10:1. The method involves determining the shape of the particular curve under measurement and calculating the SWR. The procedure is normally as follows:

a. Slide the carriage to obtain a minimum point and adjust the indicating meter for a convenient reading.

b. Locate the point on each side of the minimum where the power output level is twice that of the minimum (3 dB).

c. Determine one wavelength of the frequency of interest on the line or guide. One-half wavelength on the line is equal to the distance on the scale between two adjacent minima. Twice the quantity would be one wavelength of the carrier frequency (λ_g).

d. Compute the SWR by referring to Figure 2-4.

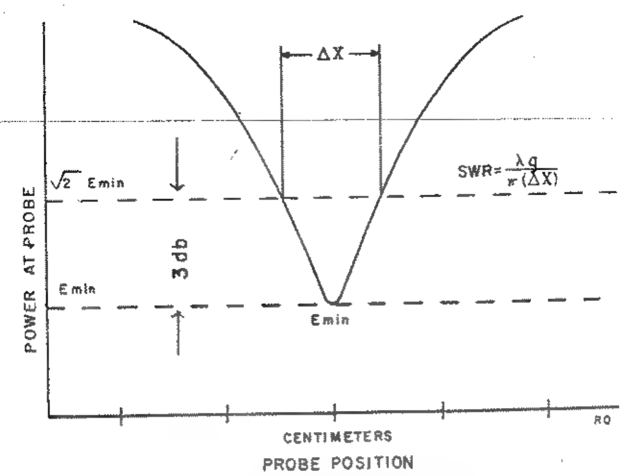


Figure 2-4. Graph Showing Double Minimum Method for Computing SWR

2-47. IMPEDANCE MEASUREMENT.

2-48. At frequencies where the slotted section is useful, transmission systems are electrically long and it becomes necessary to refer impedance to an arbitrary plane. This plane may be located anywhere along a transmission system, but the end of the slotted section is chosen for convenience. The general procedure for measuring impedance is to measure the SWR produced by the load upon the system, and also the shift in position of that SWR pattern when the load is replaced by a short. A waveguide shorting plate would be used with the Model 809C.

. In the discussion which follows, all impedances will be considered as normalized to the characteristic impedance of the slotted section. Normalization consists of dividing all impedances by the characteristic impedance of the transmission line. In the following discussion all normalized impedances will be represented by lower case type. In the normalized system the transmission line will have a characteristic impedance of unity.

2-50. MEASUREMENT PROCEDURE. The technique for performing an impedance measurement is as follows:

a. Connect the load under test to the slotted section (see Figure 2-2) and measure the SWR and the position of the minimum in the standing wave pattern.

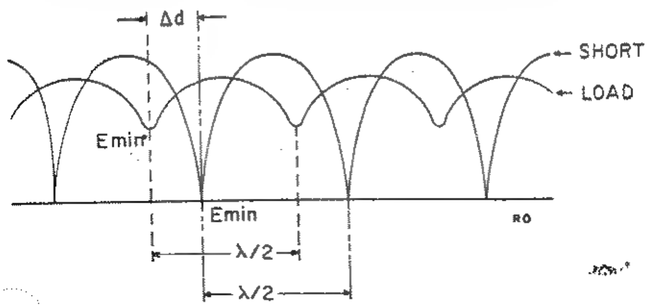


Figure 2-5. Graph Showing Standing Wave Patterns with a Load and Short

b. Replace the load with a shorting plate at the end of the slotted section.

c. Determine the new minimum position with the line thus shorted.

d. The normalized load impedance may be computed by the formulas below (refer to Figure 2-5) or on a Smith chart (may be entered with the SWR and wavelengths of minimum shift directly to obtain impedance).

$$Z_L = \frac{1 - j\,(\mathrm{SWR}) \tan X}{(\mathrm{SWR}) - j \tan X}$$

where

$$X = \frac{180^\circ \ (\pm \Delta d)}{\frac{\lambda}{2}}$$

$\pm \Delta d$ = Shift in centimeters of the minimum point when the short is applied.

Δd takes a positive (+) sign when the minimum shifts toward the load.

Δd takes a negative (-) sign when the minimum shifts toward the generator.

$\frac{\lambda}{2}$ = One-half line or guide wavelength. It is the distance in centimeters as measured between two adjacent minima.

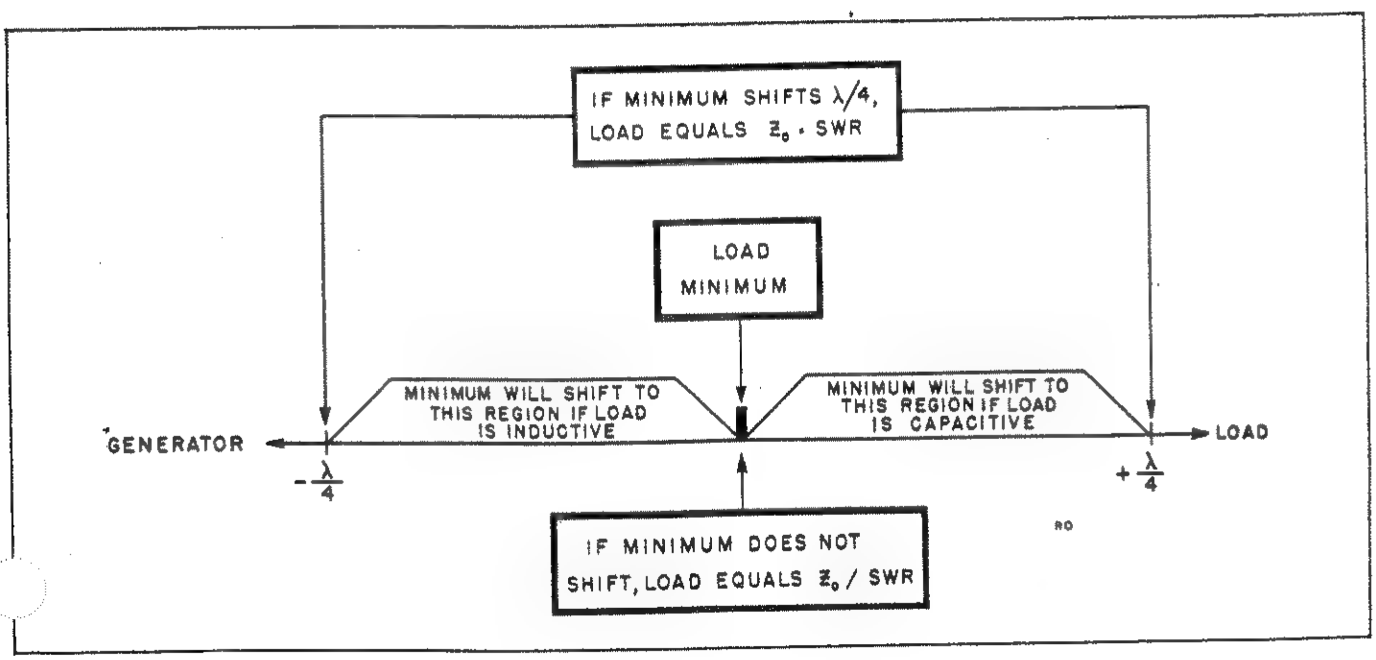


Figure 2-6. Summary of Rules for Impedance Measurement

2-51. RULES FOR IMPEDANCE MEASUREMENT. The calculations above are based upon the assumption that no losses occur in the transmission system. For laboratory setups where line lengths are short, this assumption is customary. It is also assumed that the characteristic impedance (Z_o) for the lines is entirely resistive. Since the minima occur at each half wavelength, the maximum shift that need be considered is a quarter wavelength on each side of the initial reference position. Several rules may be forulated in considering the concept.

a. The shift in the minimum after the load has been shorted is never more than $\pm \lambda/4$.

b. If shorting the load causes the minimum to move toward the load, a capacitive component exists in the load.

c. If shorting the load causes the minimum to shift toward the generator, an inductive component exists in the load.

d. If shorting the load causes no shift in the minimum, a completely resistive load exists equal to Z_o/SWR.

e. If shorting the load causes the minimum to shift exactly $\lambda/4$, the load is completely resistive and has a value of Z_o x SWR.

f. When the load is shorted the minimum will always be a multiple of $\lambda/2$ from the load. These rules are summarized in Figure 2-6.

2-52. IMPEDANCE MEASUREMENT AND THE SMITH CHART. Impedance cannot be measured directly. It is only by using a Smith Chart that measurements of SWR made with a slotted section can be translated into needed information concerning impedance without resorting to lengthy and laborious calculations. See the Appendix for an explanation of the Smith Chart.

2-53. The results given in the examples above may be found by using the Smith Chart. In addition, any shift (not only just exact quarter-wavelengths) can be computed by use of the Smith Chart. With the same setup as used for measuring SWR, proceed as follows:

a. With the load connected, slide the carriage along the slotted line and locate a voltage maximum position. Tune probe detector circuit (if any) for maximum voltage. Note 809C scale reading.

b. Adjust probe depth for the least coupling that will allow a reading on the SWR Meter with the meter RANGE switch set to 40 dB.

c. Adjust GAIN control on SWR meter so that the meter indicates 1.0.

d. Slide the carriage along the slotted line to find a voltage minimum position. Do NOT retune probe detector circuit. Note 809C scale reading.

e. Read SWR directly on the SWR meter scale in conjunction with the RANGE switch (see instruction manual for SWR meter).

f. Replace the load with a short. Slide the carriage along the slotted line to find another voltage minimum position. Note the scale reading on the carriage and whether the shift was toward the signal generator or toward the load.

g. Determine the decimal fraction part of a wavelength that the minimum has shifted by subtracting the scale readings on the carriage of the two minimums and dividing the result by wavelength of the frequency under test. Wavelength (cm) = 3×10^{10} /frequency (Hz).

h. With a ruler draw a line on the Smith Chart from the center (point 1.0 on the zero reactance line) to the circumference through the point on the outside scale corresponding to the decimal fractional part of a wavelength determined in step g. Choose proper scale (toward generator or toward load).

i. With the compass point at the center of the Smith Chart (point 1.0 on the zero reactance line), set the compass arm to the figure corresponding to the SWR on the zero reactance line.

j. Swing the compass arm to touch the line drawn in step h. The point where the compass arm touches the line is the impedance of the load in normalized form.

k. To find the actual impedance, multiply the result in step j by the characteristic impedance, Z_o.

2-54. The above procedure can be clarified by means of the following example. Suppose that a load is connected to the slotted line and found to have a SWR of 2:1 and that the scale reading on the carriage is 10 cm. On removing the load and applying a short (note this order) the scale reading on the carriage at the minimum is now 11.25 cm, the shift being measured towards the generator end of the line. The frequency of operation is 3.0 GHz, or a wavelength of 10 cm. Shift of minimum voltage = (11.25-10)/10 = 0.125 wavelengths = X, and from the formula-

$$z_L = \frac{1 + j\sigma \tan \beta X}{\sigma + j \tan \beta X}$$

where $\beta = \dfrac{2\pi}{\lambda}$ we derive,

$$z_L = \frac{1 + j2 \tan \frac{\pi}{4}}{2 + j \tan \frac{\pi}{4}} = \frac{1 + j2}{2 + j1}$$

$$= 0.8 + j0.6 \text{ (normalized impedance).}$$

2-55. To calculate the above by means of the Smith Chart, draw a line (see Figure 2-7) from the center of the chart (point 1.0 along the zero reactance line) to the circumference through a point on the scale corresponding to 0.125 wavelengths toward the generator. With a compass point at the center of the chart set the arm to 2.0 (SWR), swing arm 180° to point "A" (1/SWR, minimum position), draw an arc and the line intersect (point "B"). This is the normalized impedance (z_L). Multiply 0.8 + j0.6 by the characteristic impedance (Z_o) to find the true value.

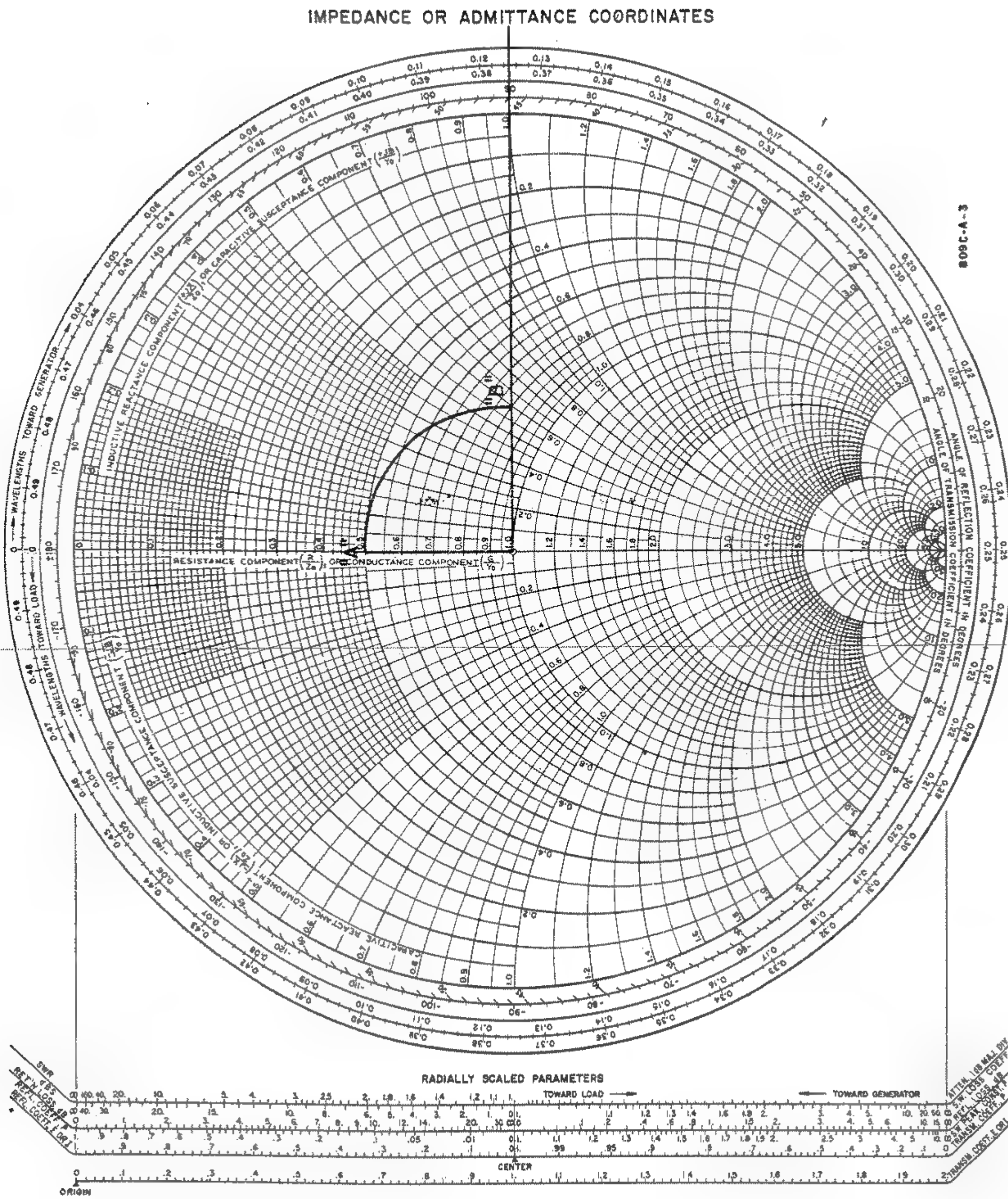


Figure 2-7. Smith Chart

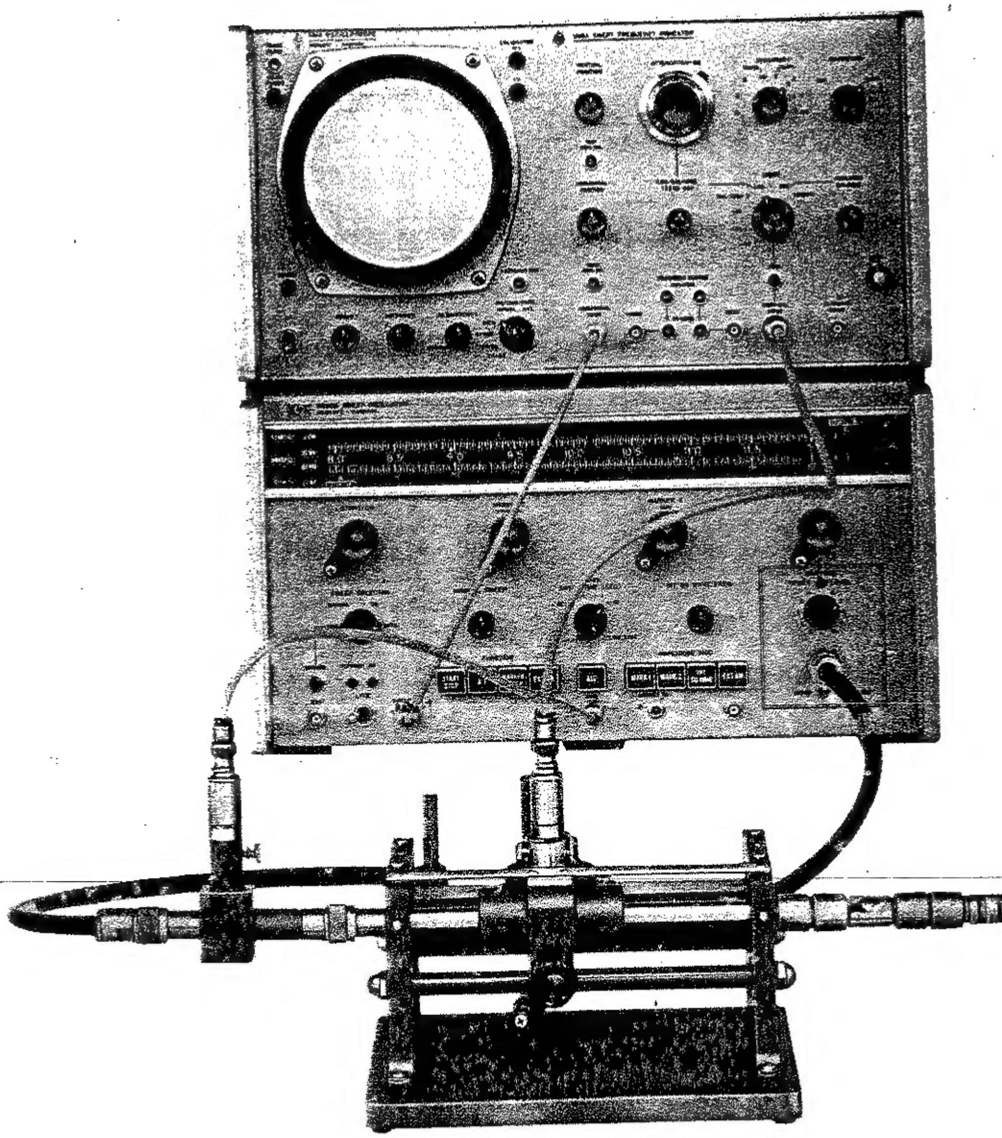


Figure 2-8 Swept Slotted Line SWR Setup

2-56. EFFECT OF RESIDUAL REFLECTIONS. The residual reflections in the transmission line will cause an error in reading the SWR of a load and also in measuring the shift of the minimum when a short is applied. The equations showing the net result are rather complicated but can be summarized easily as follows:

Let residual SWR = σ_r

Let true load SWR = σ_L.

Then the maximum SWR that will be read is

$$\sigma_L \sigma_r$$

and the minimum SWR that will be read is

$$\frac{\sigma_L}{\sigma_r} \quad \text{or} \quad \frac{\sigma_r}{\sigma_L},$$

whichever ratio is greater than 1.

2-57. The maximum error in determining the shift of the minimum will be $(\sigma_r - 1)/2$ wavelengths, and this maximum error will occur only with certain purely reactive loads.

2-58. SWEPT FREQUENCY MEASUREMENTS.

2-59. The 809C/816A-448A combination can also be used for swept-frequency measurements. Many times out-of-specification "holes" can be missed with single frequency measurements. Swept measurements will reveal these holes if the sweep is slow enough.

2-60. Swept-frequency techniques are fully covered in Application Notes 65 and 84, available from your nearest HP field office. This discussion will cover only the use of slotted lines in swept-frequency SWR measurements.

2-61. Swept-frequency SWR measurements differ from fixed-frequency measurements in that a sweep oscillator is used as a signal source and a storage oscilloscope is used as the recording device (a standard oscilloscope could also be used if a time exposure picture of the trace can be made). All possible values of SWR are displayed by moving the slotted line probe over at least a half-wavelength. A vertical line is traced out and stored on the storage oscilloscope. The top of the line represent the maximum of the SWR pattern of the device under test and the bottom represents the minimum of the SWR pattern at this particular frequency. At a different frequency another vertical line will be traced at another position on the X axis of the oscilloscope as the carriage is moved, the storage oscilloscope will store a smeared pattern of which the envelope width is a function of SWR versus frequency. The oscilloscope presentation is linear, the SWR is

$$SWR = \frac{E_{max}}{E_{min}}.$$

However, it is better if the vertical presentation is logarithmic. The display height will then be

$$\log_{10}E_{max} - \log_{10}E_{min} = \log_{10}\frac{E_{max}}{E_{min}} = \log_{10}SWR.$$

The widest part of the pattern will be its maximum SWR. This can be converted to voltage ratio from any standard table relating decibles to voltage ratio, or the SWR can be calculated from

$$SWR = \log^{-1}\frac{dB}{20}.$$

For instance, a reading of 1.65 dB gives an SWR of 1.21. This technique allows SWR to be measured very rapidly and accurately.

2-62. To level the sweep oscillator so that the power tracks probe frequency response throughout the band, the 448A Slotted Line Sweep Adapter is used as a broadband coupler/detector in the leveling feed-back loop (see Figure 2-8). The 448A consists of a short section of the 816A Slotted Line and a detector identical to the one used in the slotted line. These two detectors are matched pairs and are both provided with the 448A.

CAUTION

Replace these detectors only in matched pairs.

2-63. OPERATION.

2-64. After both probes are inserted into the 448A Slotted Line Sweep Adapter and the 809C Carriage, the sweep oscillator power level is reduced until the output power is leveled as indicated by the leveling light on the oscillator or the oscilloscope presentation. To adjust the output of the detector to be within its square-law range:

a. Set the oscilloscope for linear presentation and 1-mV/cm sensitivity. Place the device to be tested on the end of the slotted line, start the sweep, and position the carriage for maximum voltage on the oscilloscope. Set the probe for a 5-cm trace (5 mV) at maximum signal.

b. To operate, with the device to be tested connected to the slotted line, set the oscilloscope for logarithmic presentation, and move the carriage as the frequency is swept rapidly. Readout is directly in decibels of SWR,

$$SWR = \log^{-1}\frac{dB}{20}.$$

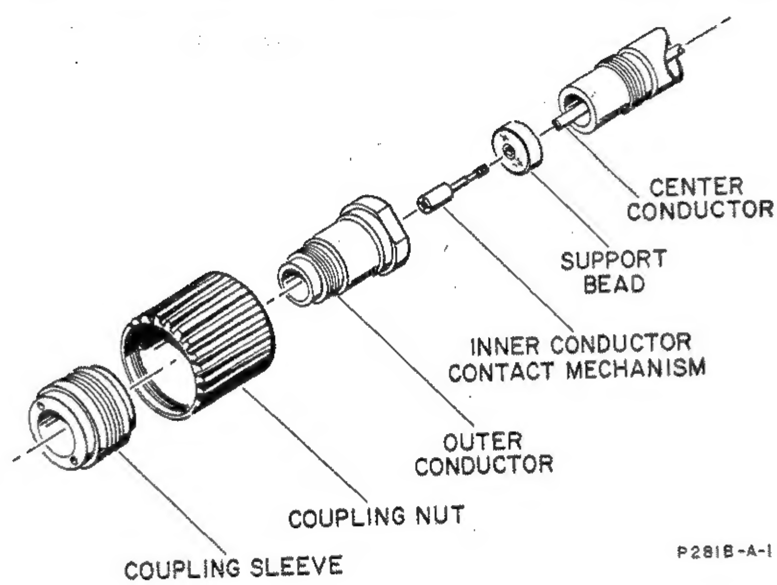
For further information, consult the Model 817A system manual supplied with the Model 448A.

2-65. ERRORS.

2-66. Since the oscilloscope is calibrated in terms of square-law operation of the detector, the signal level from the detector must be below 5 mV for a square-law error small enough (< 0.05 dB) to be neglected. This can be checked easily on the oscilloscope by switching to the linear mode of operation and measuring the output voltage from the detector with known step increases in power. The error shown on the oscillosocpe should be 0.02 dB/dB or less.

2-67. The residual SWR of the slotted line is the limiting error. The total residual SWR, including line slope, for the 816A Slotted Section and 809C Carriage is less than 1.03 up to 12.4 GHz and less than 1.04 through 18 GHz with the APC-7 connector.

2-68. To minimize the effect of error due to reflections from the probe in a slotted line, the least amount of probe penetration should be used consistent with the sensitivity of the display unit. For further information see Application Note 84, obtainable from your nearest HP office.



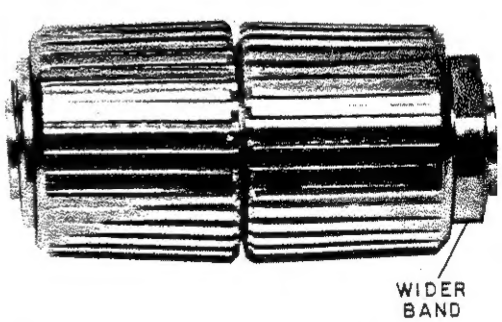
USE

To Connect:

1. On one connector, retract the coupling sleeve by turning the coupling nut counterclockwise until the sleeve and nut disengage.
2. On the other connector, fully extend the coupling sleeve by turning the coupling nut clockwise. To engage coupling sleeve and coupling nut when the sleeve is fully retracted, press back lightly on the nut while turning it clockwise.
3. Push the connectors firmly together, and thread the coupling nut of the connector with retracted sleeve over the extended sleeve.
4. Do NOT tighten the other coupling nut since this will tend to loosen the electrical connection.

To Disconnect:

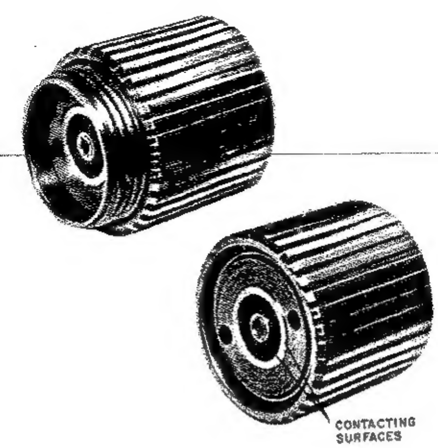
1. Loosen the coupling nut of the connector showing the wider gold band.



2. IMPORTANT: Part the connectors carefully to prevent striking the inner conductor contact.

CARE

1. Keep contacting surfaces smooth and clean. Irregularities and foreign particles can degrade electrical performance.



2. Protect the contacting surfaces when the connector is not in use by leaving the coupling sleeve extended.
3. Use lintless material and/or firm-bristled brush such as tooth brush for cleaning. If a cleaning fluid is needed use isopropyl alcohol. IMPORTANT: Do not use aromatic or chlorinated hydrocarbons, esters, ethers, terpenes, higher alcohols, ketones, or ether-alcohols such as benzene, toluene, turpentine, dioxane, gasoline, cellosolve acetate, or carbon tetrachloride. Keep exposure of the connector parts to both the cleaning fluid and its vapors as brief as possible.

Figure 2-9. APC-7 Connectors

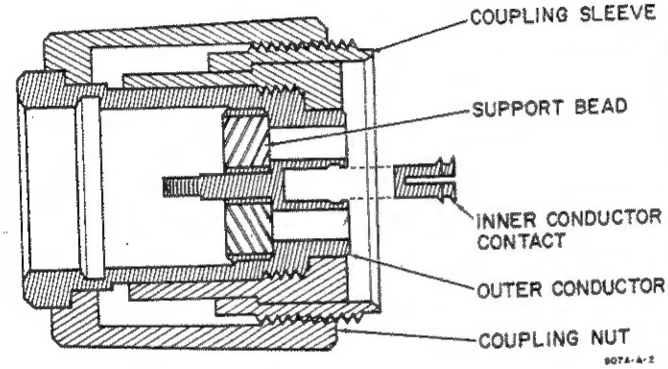
REPLACING AMPHENOL APC-7 CENTER CONTACT

Through wear or damage the contact in the center conductor may need replacing. This contact is a small four-pronged collet which snaps into a recess in the center conductor. This contact is normally held in by the spring-action of the four prongs. With a magnifying glass examine this contact to determine if it needs replacement. DO NOT REMOVE THIS CONTACT FOR INSPECTION (it may be damaged by removing). The contact should be free of burrs or wear and the prongs should be equally spaced. If the contact is removed do NOT re-use it (it may be damaged by removal). This contact is Amphenol* part number 131-129 and HP 1250-0907. If this contact needs replacement and a new contact is available proceed as follows:

a. Place the instrument so the connector faces down, if possible.

b. Tap the connector lightly and the contact should now protrude slightly. Insert the centering pin of the HP contact extractor, part number 5060-0236, with the jaws open. If this tool is not available, an ordinary draftsman's mechanical pencil may be used (the end of the jaws may have to be filed to get a good grasp at the very end).

c. Allow the jaws on the tool used to close and pull straight away from the connector without twisting. The contact should come with the tool. If not, repeat the process. Do NOT re-use the contact.



Amphenol* APC-7 Connector

d. Snap in a new contact by pushing a new contact in place.

Other tools, such as open-end wrench HP part number 8710-0877 and spanner wrench HP 5060-0237 are available for working on these connections.

*Amphenol RF Division, Danbury, Conn.

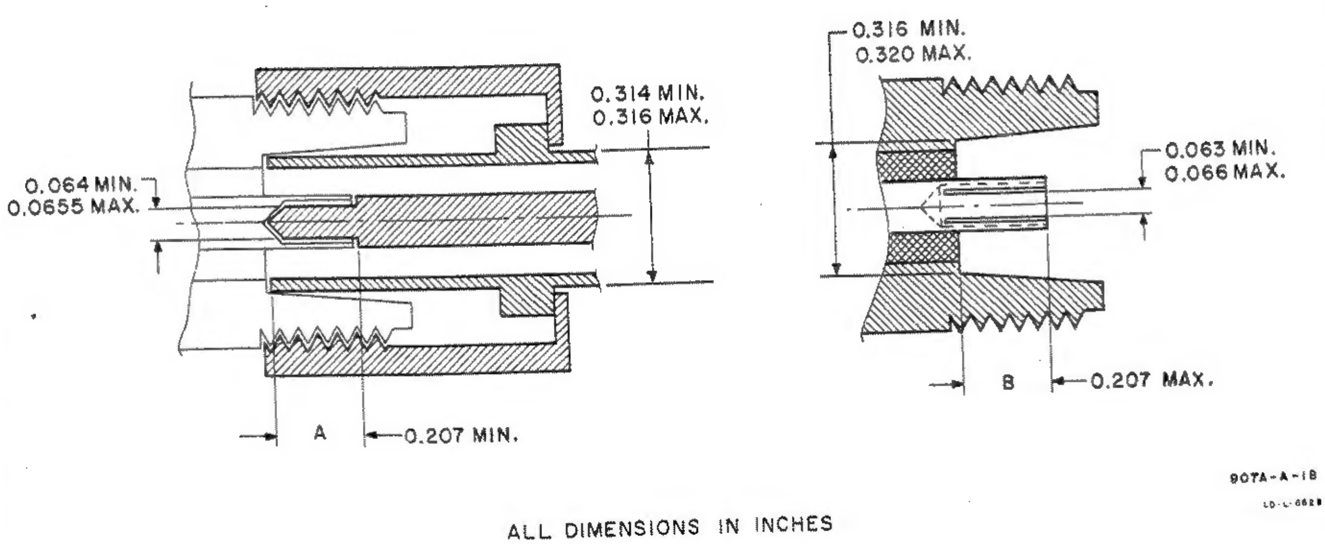


Figure 2-10. Type N Connector